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REVIEW ARTICLE

Interactive visualization of three-dimensional maxillofacial prosthetic data in portable document format: A potential new approach for scientific publications

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ABSTRACT

Rendering three-dimensional (3D) structures of maxillofacial prosthetics within a single two-dimensional (2D) document offers great opportunities for the readers of scientific publications to interactively visualize these structures with in-depth 3D perception. The capabilities of Portable document format (PDF) have not yet been fully utilized in maxillofacial prosthetics publications especially when considering that PDF is the most common file format for publishing articles. This article briefly reviews the application of PDF in the visualization of 3D data within scientific publications. It also introduces an effective interactive visualization approach by embedding 3D data into PDF file for journal publications and discuss its impact on maxillofacial prosthetic publications. It emphasizes on the usage of this electronic document, when used to its full potential, could be used to illustrate embedded 3D interactive maxillofacial prosthetic data, which can be viewed and manipulated by the reader without the need for specific 3D viewing softwares. Thus, this article compiles the capabilities of PDF which is beyond just an electronic documentation exchange and viewing static 2D structures in scientific publications. (*Int J Maxillofac Prosthetics 2019;1:2-8*)

INTRODUCTION

The glossary of prosthodontic terms has defined maxillofacial prosthetics as the branch of prosthodontics concerned with the restoration and/or replacement of the stomatognathic and craniofacial structures with prostheses that may or may not be removed on a regular or elective basis.[1] Maxillofacial prosthetics deals with complex three-dimensional (3D) head and neck structures which is considered to be one of the most challenging and unique dental field. Digital technologies have revolutionized prosthodontics in general and maxillofacial prosthetics in specific.[2] Various digitization approaches have been used, which include but not limited to cone beam computed tomography, computed tomography, magnetic resonance imaging, laser surface scanners, intraoral scanners, optical scan systems, and 3D photogrammetry systems.[3-9] These digitizing systems provide very clear 3D topographic data of the maxillofacial defects.

Proper visualization of digitized data play an important role in interactive treatment planning and delivery of definitive prostheses in maxillofacial prosthetics.[10] In order to visualize data, free and commercial visualization software have been used to provide interactive 3D visualization of maxillofacial defects.[11] However, in scientific publications, the visualization is traditionally limited to the static two-dimensional (2D) illustrations. This may prevent readers from expanding their access to the most important aspects of the information within these structures. Although some scientific journals and publishers have allowed authors to link their 3D supplementary materials to the original articles,[12, 13] it could require readers to have specialized 3D visualization software and tools. An alternative approach which allows readers to interact with an accessible document for effective visualization of 3D information without needing to install additional software is essential in the field of maxillofacial prosthetic publications.

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The Portable Document Format (PDF) is a standard and common electronic document that have been used by journals and publishers for the exchange of scientific publications.[14] A single PDF file can include all the necessary information and resources to fully describe the layout and the content of an electronic document, which include texts, illustrations, multimedia and even 3D data. Although, it fulfills all requirements for an interactive publication document,[15] it has not yet found its way into maxillofacial prosthetic publications. Therefore, this article briefly reviews the application of PDF in the visualization of 3D data within scientific publications. It also introduces an effective interactive visualization approach by embedding 3D data into PDF file for journal publication and discuss its impact on maxillofacial prosthetic publications.

3D PDF IN SCIENTIFIC PUBLICATIONS

Since the late 1990s, almost all the journal publishers have adopted PDF as a standard outlook file type for their electronic publications and distribution workflow. For proper understanding of any published scientific article without losing important information, the visualization of this data should be in 3D mode whenever possible.[16] The first application of PDF with embedded 3D data was published in three different articles in 2008. Barnes and Fluke[17] have demonstrated that the new 3D extensions to the PDF standard can be used to publish instructive and interactive 3D figures in astronomy research papers. Ruthensteiner and Heÿ[18] have used surface models to demonstrate the effectiveness of interactive 3D models for electronic publications and proposed 3D illustrations to become a standard in life science publications. Kumar et al[19] have described how an interactive 3D model of a molecular complex can be embedded directly into a PDF, thus providing readers with important and educational visual information that would otherwise be more difficult to disseminate. Since then, more than 34 PDF articles have been published with embedded 3D data in clinical communication and biomedical scientific publications.[14] However, the first application of PDF with embedded 3D data in dentistry was published in 2011. Danz and Katsaros[20] have described a simple way to present 3D surface data of orthodontic models with their analyses that can be used in articles or diagnostic reports. All the above mentioned studies have proven the suitability and usefulness of PDF for interactive visualization of embedded 3D data for electronic publication.[14]

Maxillofacial prosthetic articles are mainly published within prosthodontic journals whereas maxillofacial prosthetic journals is limited to the newly established open access journal called the International Journal of Maxillofacial Prosthetics.

Up to date, no article has been published in the prosthodontic literature that mentioned or embedded 3D data within PDF article, except for an article that was written by the author and published in the International Journal of Prosthodontics.[21] This article introduced a 3D data documentation method for effective interactive digital visualization in maxillofacial prosthetics using a PDF format. The International Journal of Maxillofacial Prosthetics has adopted this approach for all its publications that contain 3D data.

EMBEDDING 3D DATA INTO PDF

To highlight the capability of this approach in the field of maxillofacial prosthetic publication, two fully interactive 3D maxillofacial prosthetic examples are presented in this article; a simple maxillary obturator prosthesis and a twin-block brachytherapy palatal mold. A 3D maxillary obturator prosthesis for edentulous maxillectomy defect was used. This obturator was three-dimensionally digitized using intraoral scanner Trophy 3DI PRO α (Yoshida Dental Trade Distribution Co., Ltd. Tokyo, Japan) to produce a virtual 3D colored obturator, and saved as a polygon (PLY) file format. The PLY format was then converted to the universal three-dimensional (U3D) file format using Meshlab 3D converter software (Meshlab, Visual Computing Lab, ISTI-CNR). This U3D model was then imported into a professional PDF software, Adobe Acrobat Pro DC (Adobe Systems, Mountain View, CA, USA), and embedded within this document (Fig 1). In addition, multiple 2D images representing various surfaces of the maxillary obturator prosthesis were taken and placed within the PDF file for visualization compression (Fig 2).

The second example is a twin-block brachytherapy palatal mold. Figure 3 shows the schematic drawing of this complex structure of the mold. It contains a carrier part which adapted to the fitting surface of the palate, facing the tumor and carry the radiation seeds (grain). The other part of the mold is the shield which protects the non-tumor tissue from exposing to unnecessary radiation by embedding a 4 mm thickness of lead layer.[22] The two parts of mold were three-dimensionally digitized using intraoral scanner Trophy 3DI PRO α (Yoshida Dental Trade Distribution Co., Ltd. Tokyo, Japan) to produce a virtual 3D mold, and saved as a polygon (PLY) file format. All 3D virtual models were then imported to MeVisLab (http://www.mevislab.de/). The modular design of "Scientific3DFigurePDFApp" within MeVisLab allows for models from different sources to be combined and their U3D properties (color, name, position in the object tree) can be specified.[23] Therefore, it was possible to create surface meshes of all relevant structures (Twin-block mold, lead layer, and radiation seeds) in a single U3D file format. This U3D file was then imported into a professional PDF software, Adobe Acrobat Pro DC, and embedded within this document (Fig 4).

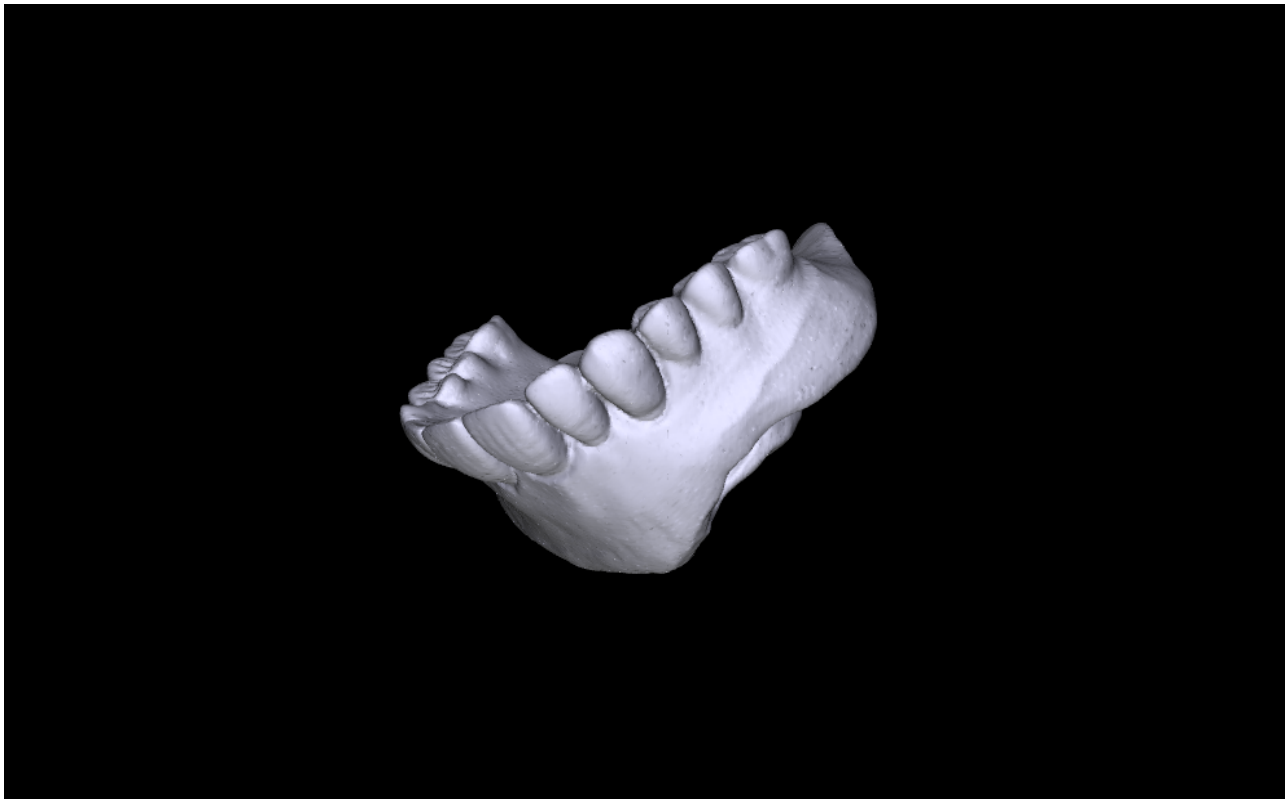

Fig 1. An example for a simple interactive 3D model embedded within PDF file, this example shows a maxillary obturator prosthesis for edentulous maxillectomy defect that can be visualized in 3D mode.

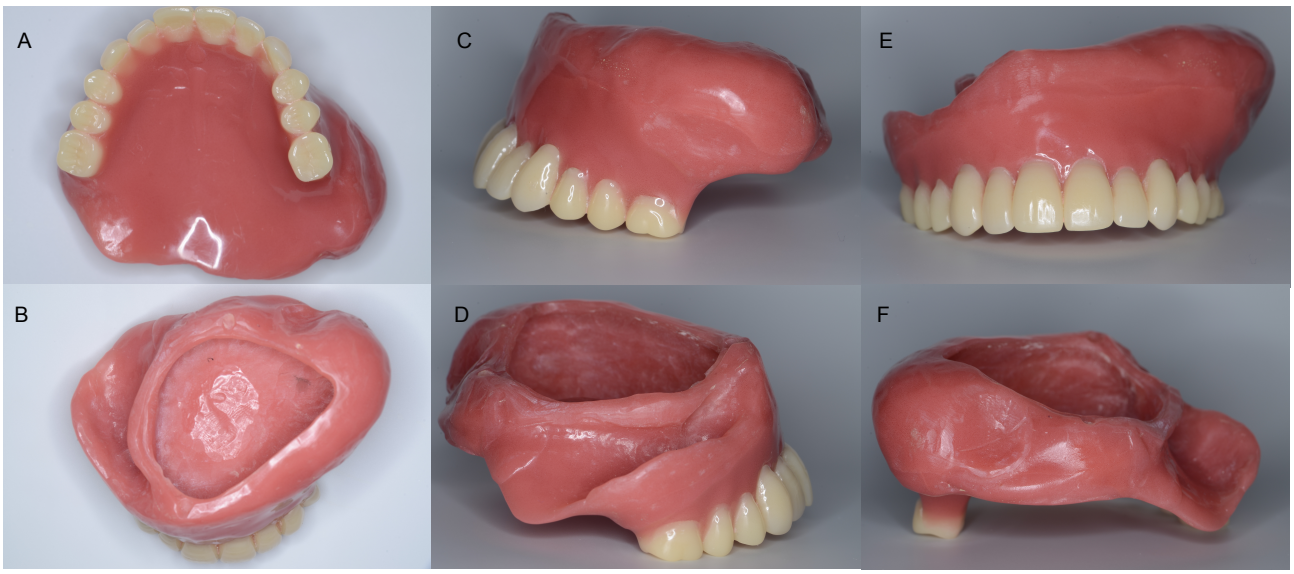

Fig 2. Multiple 2D images representing various surfaces of the maxillary obturator prosthesis. A. Occlusion surface, B. Fitting surface, C. Lateral view (left), D. Lateral view (right), E. Anterior view, F. Posterior view.

Using default activation settings and assigning a poster image from default view, the 3D visualization parameters were set as follows: dark background, CAD optimized lights, solid rendering style and default 3D conversion settings. In addition, multiple 2D images representing various parts and surfaces of the mold were taken and placed within the PDF file for visualization compression (Fig 5). The final PDF file for publication was then saved as a reduced-size PDF file which can be opened and fully operated by Adobe Reader.

By clicking on the image, the interactive 3D model is activated, and the reader can move it in space. A navigation bar that appears on the top of the image allows for visualization of preselected views, selection of projection type and other effects (shading, lights, and background color). The model tree on the left part of the PDF document shows that this twin-block brachytherapy palatal mold consists of 4 interactive parts: carrier, shield, lead layer, and radiation seeds. Settings such as visibility, transparency, and shading can be individually selected for each part with a right mouse click on the specific part of the model tree. various animations can be added to the mold.

IMPACT ON MAXILLOFACIAL PROSTHETIC PUBLICATIONS

Considering the fact that maxillofacial defects are complex 3D structural defects, the prosthetic rehabilitation should follow this geometry to gain a proper fit and to restore function and aesthetics. From a maxillofacial prosthetic point of view, representing these 3D structures within a single 2D document offers great opportunities for the readers to interactively visualize 3D data with more in-depth perception. As seen in the above examples, it needs multiple 2D figures to have a comprehensive view of the structure and still some of the hidden aspects like undercuts can't be fully viewed. On the other hand, only one 3D model embedded within a PDF file can comprehensively express all the details of the object including the depth. It is also important to point out that PDF is a universal accepted file format for the publication of all prosthodontic journals which is the most preferred venue for maxillofacial prosthetic articles. The advantage of using PDF files with embedded 3D data within the publications is that they are available as a single download which can be viewed online or offline based on the reader's choice.

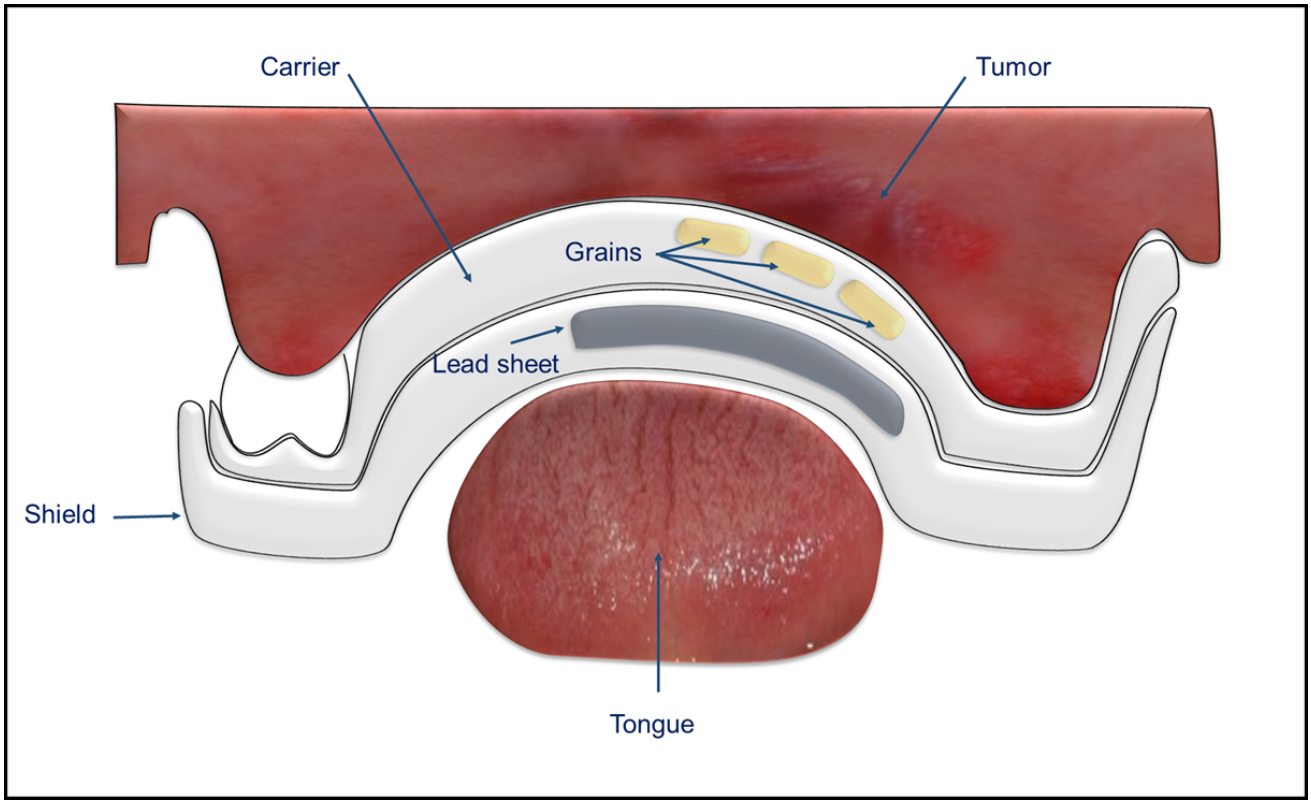

Fig 3. Cross sectional schematic drawing of the complex structure of the mold .

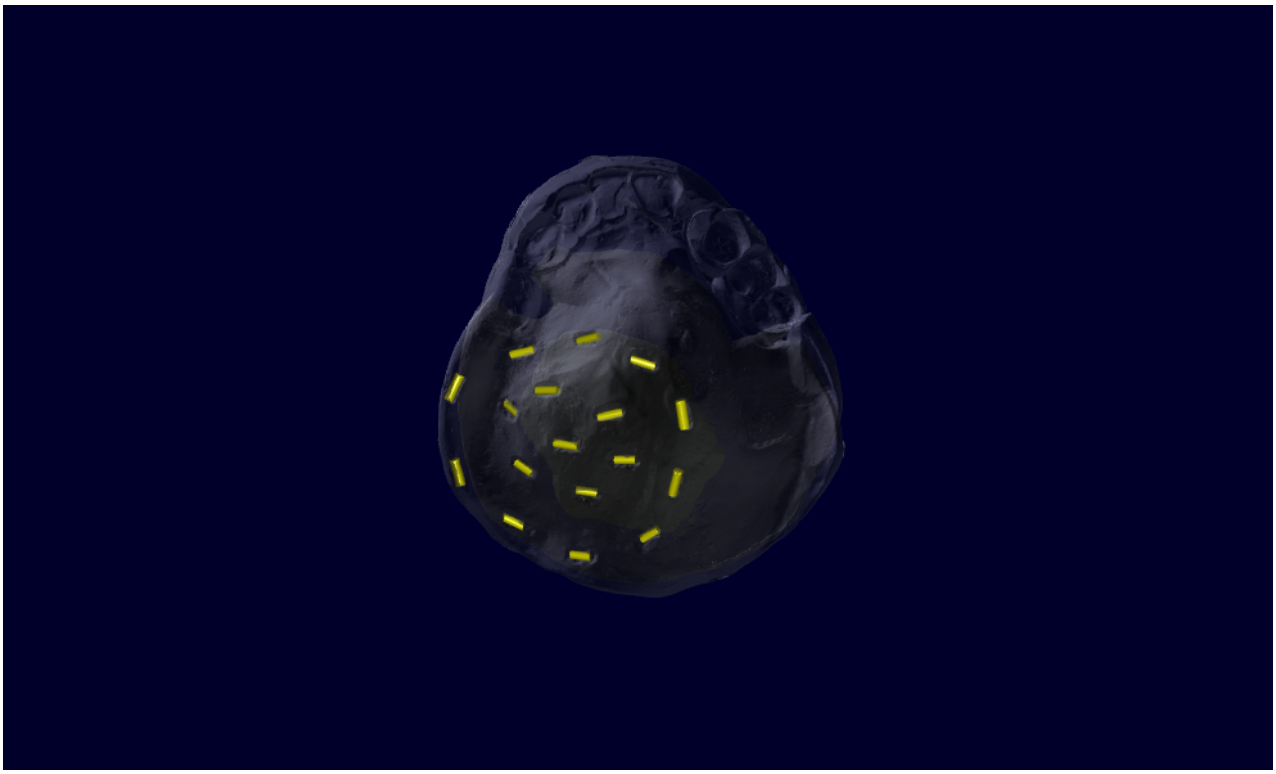

Fig 4. An example for a complex interactive 3D models embedded within PDF file as a single U3D file, this example shows a twin-block brachytherapy palatal mold as a radiotherapy appliance for palatal tumor that can be visualized in 3D mode.

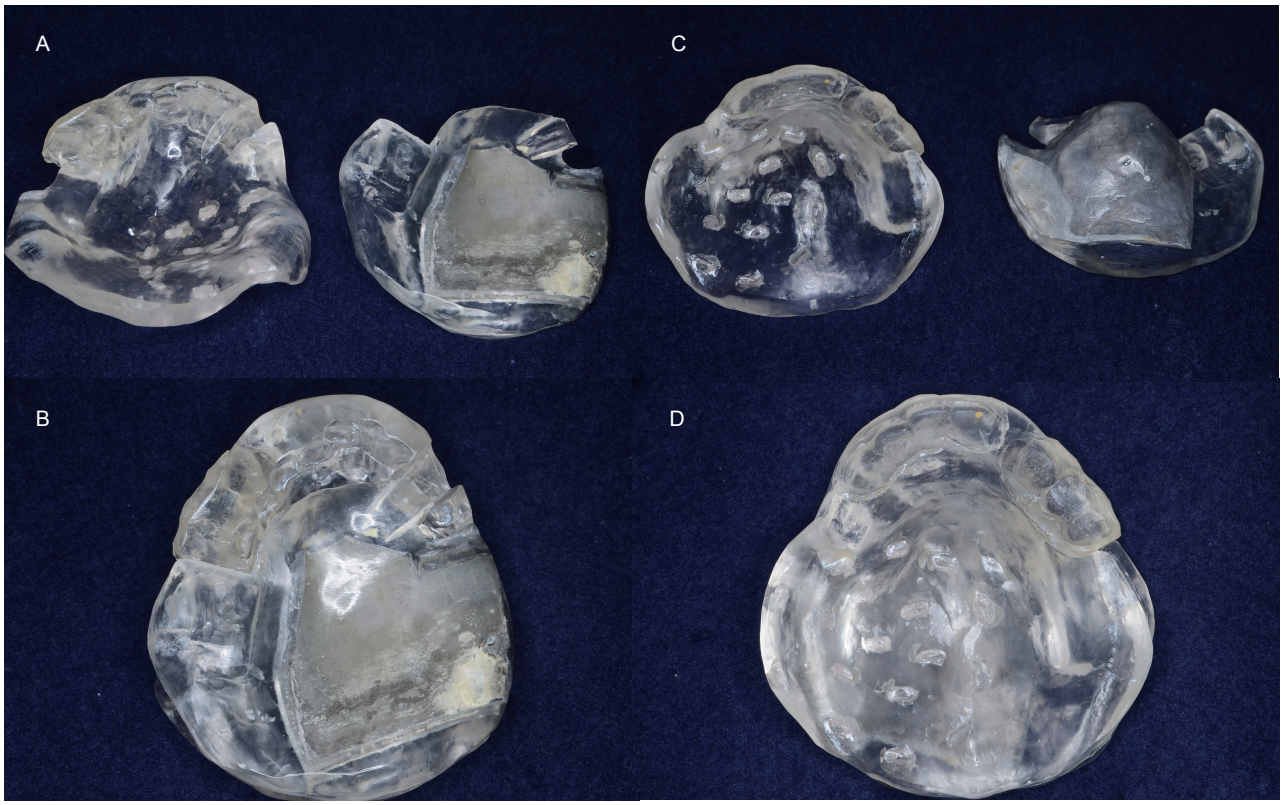

Fig 5. Multiple 2D images representing various parts and surfaces of a twin-block brachytherapy palatal mold. A. Occlusion surface for carrier and shield parts. B. Occlusion surface of combined parts, C. Fitting surface for carrier and shield parts, D. Fitting surface of combined parts.

Following the current global trend towards more openness and transparency in the production and dissemination of scientific knowledge, it seems that PDF articles with integrated 3D data are more suitable for electronic open access publishing scheme. This freely allows the readers to interactively manipulate embedded 3D data content within the electronic PDF document. It also eliminates the issue of 3D data size and PDF file size, where scientists can simply send each other an article direct website link without the need to send it by email, thus resulting in the widespread dissemination of maxillofacial prosthetic articles. Several studies have shown the benefits of electronic open access including the rapid dissemination of research outcomes as well as the increased number of open access articles citations.[24]

Management of maxillofacial defect patients has evolved to include a multidisciplinary approach requiring collaboration between medical and dental team members to achieve an effective treatment plan.[25] The above mentioned 3D model of the twin-block brachytherapy palatal mold is a good example for multidisciplinary approach to manage localized palatal tumors. Participation of head and neck oncologist, oral and maxillofacial radiologist, oral and maxillofacial surgeon, maxillofacial prosthodontist, and dental technologist are necessary to work together in order to manage such tumor. Reading published PDF articles with integrated 3D data by those members will enhance the awareness of the considerations for maxillofacial prosthetic treatment through interactive visualization of the 3D data. However, this approach should not replace the use of raw data within a database, which permits a more comprehensive exploitation of 3D information. It is therefore important to be considered as an effective tool for publication of maxillofacial data in reprocessed format that eliminates the need of advanced knowledge of visualization software.

Animated 3D data within a single PDF article is another aspect that can be achieved with great impact on maxillofacial prosthetic publications. This is in particular important as the perspective of the maxillofacial structure can be chosen and varied. Complex 3D models can be masked to show only selected parts of interest. In addition, simulation of functional movements of various maxillofacial prostheses can be animated and visualized within this approach. However, illustration of 3D animation software is needed for complex maxillofacial prosthetic motions.

CONCLUSION

This article concludes that PDF is beyond an electronic document for exchanging and viewing the static 2D publications. It is an electronic documentation that can be illustrated for embedding 3D interactive maxillofacial prosthetic data which can be viewed and manipulated by the reader without the need of specific 3D visualization software. Therefore, PDF documents with integrated 3D data provides a new approach of visualizing complex maxillofacial prosthetic structures in an interactive and more informative mode which is appropriate for maxillofacial prosthetic publications.

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